Mapping the Nearshore Using a Unique Towfish

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by

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ABSTRACT

Vandermeulen, H. 2011. Mapping the nearshore using a unique towfish. Can. Tech. Rep. Fish. Aquat. Sci. 2959: v + 18 p

The specifications and design of a towfish system are described for shallow water use. The towfish contains a color video camera, high frequency sidescan and positioning transponder. The towfish offers rapid 'transect' views of the bottom useful for describing habitat classes. The towfish is unique in that the video acts as a ground truth for the sidescan imagery in real time.

The transponder on the towfish interacts with a transceiver mounted to the vessel hull to produce positional data to dGPS specifications (sub-meter precision). All video is georeferenced and stored as digital video clips in MapInfo GIS projects which also include towfish tracks and high frequency sidescan images (330 kHz, 30 m swath). The GIS projects can be used to generate habitat maps.

RÉSUMÉ

Vandermeulen, H. 2011. Cartographie littorale au moyen d'un corps remorqué unique. Can. Tech. Rep. Fish. Aquat. Sci. 2959: v + 18 p

Les spécifications et la conception d'un système de corps remorqué destiné à une utilisation en eaux peu profondes sont décrites. Le corps contient une caméra vidéo couleur, un sonar à balayage latéral haute fréquence et un transpondeur de positionnement. Il permet d'obtenir rapidement des vues de « section » du fond qui sont utiles pour décrire les classes d'habitats. Le corps remorqué est unique en ce que les images vidéo servent à valider l'imagerie à balayage latéral en temps réel à l'égard de la réalité du terrain.

Le transpondeur du corps remorqué interagit avec un émetteur-récepteur monté sur la coque du bâtiment pour produire des données de positionnement de qualité DGPS (précision submétrique). Toutes les images vidéo sont géoréférencées et stockées sous forme de séquences vidéo dans des projets de SIG MapInfo, qui contiennent également les trajectoires du corps et les images à balayage latéral haute fréquence (330 kHz, couloir de 30 m). Le projet de SIG peut servir à générer des cartes d'habitat.

INTRODUCTION

Three facts remain unchanged since Vandermeulen (2007):

- Researchers within the Science Sector of the Department of Fisheries and Oceans (DFO) are frequently asked to describe, or map, bottom features such as habitat patches to guide management action.
- The equipment and methods required to map shallow (<10 m), turbid nearshore marine waters are different from those used in deeper waters.
- The equipment and methods required for the precise mapping of mid or deep water areas (e.g. 100 m) are relatively well established and commercialized. This is not the case for shallow waters.

There are several possible options for mapping shallow waters (<10 m). One group of options involves remote sensing methods like LiDAR, satellite imagery, spectral imagers (e.g. CASI), or air photos. Unfortunately, in the author's experience none of these airborne / satellite methods work particularly well in the turbid, low tidal range waters of the bays on the eastern seaboard of Canada. In this location, remote sensing methods routinely fail in waters deeper than 7 m, and the author has seen them fail in waters only 3 to 4 m deep.

Another group of options for mapping shallow waters involves placing equipment into the water column itself. Most commonly, underwater video cameras and acoustic equipment are used in this context. The author has explored acoustic options, and found that most multibeam methods do not work well in waters <10 m deep, while sidescan and single beam echo sounders hold promise.

Vandermeulen (2007) described an inexpensive, high resolution sidescan system for use in very shallow waters (to <1 m depth), coupled with a drop and towed camera system for ground truthing the sidescan imagery. The intent was to map at a bay wide scale (10s of km), which excludes SCUBA based survey methods. Of course, this same equipment can be used at smaller scales if desired (100 m or less).

The following text describes the results of continuing improvements to the original sidescan / camera systems. A towfish fusing sidescan, camera and transponder functions was developed. Another publication will describe equipment and nearshore mapping methods development for a single beam echosounder system (BioSonics, Inc.).

2.0 MATERIALS AND METHODS

2.1 Vessel, Power and Electronics

A 22' Cape Sable style Rosborough custom wheelhouse research vessel was used as described in Vandermeulen (2007). All equipment was custom fitted to this vessel with more recent modifications as described below.

The original deep cycle / gel pack battery system to run the electronics (Vandermeulen 2007) was replaced by a 1 kW gas generator[1] held at the stern deck in a specially designed metal and plastic 'doghouse' to keep it dry (Figure 1). An aluminum cowling was constructed to cover the plug / switch end of the generator to protect it from rain and wave splash (black cowling in Figure 1). The generator was chosen because the old deep cycle / gel pack battery system only provided power for about 7h between overnight charges. The generator will run for approximately 4h on one tank of fuel, allowing for one morning and one noon fill on a typical survey day.

With the use of the generator, a more flexible configuration of electronics was possible. Two AC power extension cords run from the generator into the wheelhouse, one cord terminates at a power bar to run AC components and the other feeds a 6 amp, 12.5V DC power supply[2] for DC components.

To provide navigation support independent of the generator or the larger electronics package, both the dGPS and navigation notebook computer were hardwired to the vessel's helm station DC power switch panel. A 175 watt inverter[3] provides AC power for the navigation computer at the helm. The vessels engines must run continuously to generate enough DC power to run the navigation computer inverter for extended periods of time (e.g. during surveys).

The original wooden box with metal shelving for electronics hardware (Vandermeulen 2007) was loose in the wheelhouse and unsafe in rough weather. It was replaced by a custom hardwood shelf unit bolted to the wheelhouse wall and deck for stability (Figure 2). In order to withstand rough weather, the electronics are held on this shelving by wooden brace bars, eye bolts and straps. The new shelving also offers solid hand holds for the crew. The electronics on this shelving consist of (Figure 2):

- television monitor;
- sidescan and transceiver notebook computers (all communication with electronics via COM ports, see Vandermeulen 2007);
- Horita video overlay;
- LCD monitor (this is a new addition since 2007, provides a video feed for the survey supervisor, see below);
- Shark Marine SV-DV surface console (Sony miniDV tape deck and DC power generation for the SV-16 underwater video camera on the towfish)

Two cables lead from the shelving unit via a port on the back wheelhouse wall to the stern working deck. One cable feeds the transceiver held on the break away arm mounted on the port side of the vessel (Figure 3), the other feeds the towfish. A DC switchbox on the shelving unit (Figure 2) controls power to the transceiver and towfish (sidescan and lasers).

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[1] Honda model EU 1000i inverter generator – 120V AC, 1000 W
[2] MW® model MW126A DC power supply
[3] MotoMaster Eliminator, Canadian Tire

It was discovered that the original towed camera cable (Vandermeulen 2007) had extra unused wires it that could be used to feed the sidescan and a new set of lasers. This led to the design of a new towfish to hold camera, lasers, sidescan and transponder in one package.

2.2 The New Towfish

A towfish was developed with the assistance of the engineers and machine shops at the Bedford Institute of Oceanography (BIO). A stainless steel frame was constructed to hold the towfish components. It was weighted with 7 kg of lead and outfitted with a clear plastic fin to have a stable aspect while towed behind the vessel at 1.0 to 1.5 knots (Figure 4). The towfish is composed of three main parts:

1. transponder
2. Camera and scaling lasers – the camera used for the towed camera system in Vandermeulen (2007) was retained. The original battery powered scaling lasers, however, proved to be fragile and prone to failure. They were replaced by a new 10 cm scale set of lasers[4] powered directly by a 12 V supply in the towfish cable.
3. Sidescan

The core mapping instrument on the towfish is the SportScan[5] dual high frequency sidescan (330 or 800 kHz) described in Vandermeulen (2007). The original metal SportScan body tube was replaced by a shorter custom version to fit on the towfish.

The communication between the towfish transponder and the transceiver created some acoustic interference with the sidescan – this was largely corrected by running the SportScan at 330 kHz, rather than the 800 kHz setting as described in Vandermeulen (2007), and setting both transceiver and transponder to low power mode. The 330 kHz setting provides slightly 'softer' images with no major impact on final image resolution. Settings of 8 dB gain and 30 m swath width were retained to provide the best possible image detail (Vandermeulen 2007).

The working deck davit has an arm which holds a clutch block supporting the towfish cable. The davit can be 'swung out' by its rotating base, allowing the arm to be held parallel to the hull while traveling and perpendicular to the hull while towing . A new clutch block was made to suspend the towfish in the water (Figure 5). The new clutch block had deeper sides (or 'cheeks') than the original described in Vandermeulen (2007), as well as a side plate system aligned above the clutch wheel. Both of these improvements were made to better hold the cable in place and prevent it from binding off the side of the block. Inner-tube rubber was added to the groove of the block where the towfish cable rests. The rubber increased the friction and grip on the cable on play

[4] Semiconductor scaling lasers from Shark Marine Technologies Inc. St. Catharines, Ontario. 650 nm, 7.5 mW.
[5] Imagenex Technology Corp., Port Coquitlam, British Columbia.

out (block locked), significantly reducing the weight the towfish operator has to hold while running a transect line.

A wiring diagram of the towfish and associated electronics is provided in Figure 6. The hardware and operation are described in Vandermeulen (2007) with some new details provided below.

2.3 Survey Operations

It takes a crew of three to run surveys with the new towfish system. Each individual is completely occupied by their tasks during survey runs:

1. Helmsperson – This individual controls the navigation computer and dGPS. They are responsible for keeping the vessel on course and at the correct speed (optimally 1.5 knots) along predetermined survey transects marked on the navigation computer charts, recording the vessel track with the navigation computer, monitoring the stability of the dGPS feed, radio communications and overall vessel safety and operation. The survey transects are typically run perpendicular to the shore, starting in deeper water and ending at the shore.
2. Towfish operator – This person is responsible for the stern working deck area and the towfish. They monitor and fuel the generator. They lower the towfish and transceiver arm into the water at the start of each transect, and raise them again at the end of transects. When running survey transects, they hold the towfish cable while standing in the wheelhouse back door watching the television monitor. This activity takes a great deal of concentration and stamina, as the towfish must constantly be raised or lowered to achieve proper towing depth and avoid hitting obstacles on the bottom[6].
3. Survey supervisor – This person is responsible for selecting which transects to run on any particular day, and tracking overall survey progress. They are located in the wheelhouse next to the helmsman. They call off the start and end of each transect to cue the helmsperson and towfish operator. They face the stern of the vessel while running survey transects, operating the DC power switches, the sidescan and transceiver computers and monitoring the video feed on the LCD screen while recording to the miniDV tape deck.

Each transect run involves tight coordination between crew members. The sequence is as follows:

1. The survey supervisor indicates to the helmsperson which survey transect on the navigation computer is next. The helmsperson then steams to the target. Transects can be anywhere from 100 to 700 m apart, depending upon the resolution required in the final GIS product (see below). For most surveys in Atlantic Canada, 250 m spacing is adequate to capture significant bottom features (rock reefs, eelgrass beds, mud flats, etc.) on a bay wide scale.

[6] It would cost over $12K to get a motorized slip ring reel to control the towfish cable.

2. Just before the target is reached, the helmsperson slows down the vessel to towing speed (1.5 knots, 700 RPM with our vessel) and aligns to the beginning of the transect depending upon currents and wind. The survey supervisor powers up the computers at this time (with transceiver computer COM ports unplugged, see Vandermeulen (2007).
3. Once the helmsperson is satisfied with the vessel position they place the engines in neutral and call out to the towfish operator "Drop gear in", at which point the towfish operator lowers the transceiver arm into vertical position, spins the davit arm out and places the towfish in the water, holding the cable so the towfish is just below the surface. The towfish operator then calls out "Gear is in".
4. The helmsperson then places the engines back in gear and begins to steam to the start of the transect as indicated by the navigation computer, steering and increasing RPM if required (up to 1000 RPM maximum[7]) to correct vessel track for wind and waves. Ultimately, the intent is to move down the transect as tightly as possible with a 'speed over ground' of 1.0 to 1.5 knots. This operation takes a skilled helmsperson.
5. At the same time, the survey supervisor turns on the DC power switches to the sidescan, lasers and transceiver – calling out "Power on". They then turn on the video console and start the software on the sidescan and transceiver computers (see Vandermeulen 2007 for details). In rapid sequence, the survey supervisor checks the following:
    a. the transceiver computer is producing stable towfish position updates;
    b. these updates are being accepted by the video overlay and displayed on the television monitor, LCD monitor and video consol; along with a clear video feed;
    c. the waterfall display on the sidescan computer is running, and towfish position updates are being accepted
6. If all is well, and the vessel has reached the starting point of the transect, the survey supervisor calls out "Start recording" and the following actions take place simultaneously:
    a. the helmsperson starts recording the vessel track with the navigation computer;
    b. the towfish operator releases the cable and allows the towfish to sink to the bottom, watching the television monitor to stop the towfish about 20cm off bottom, then calling out "I have bottom" – indicating to the crew that all is well with the towfish and the transect run can continue;

[7] The vessel's twin 50 hp engines use large, low pitch (9°) three blade propellers which provide excellent vessel tracking while towing at low speeds. In our experience, when an RPM of >1000 is required to hold the vessel on track it usually means that conditions for survey work are marginal in any case – winds of >25 knots and / or waves >1 m.

c. the survey supervisor turns on the recording functions of the sidescan computer, transceiver computer (to record the towfish track), and SV-DV video console – taking note of the transect number and start time in a field notebook.

7. The helmsperson continues steering the vessel along the transect. Some transects are over one hour long but most are 15 minutes or less. During this time the towfish operator raises and lowers the towfish to keep it about 20 cm off bottom and indicates if the towfish has become caught on an obstacle (rare but possible in areas with fishing or aquaculture gear). The survey supervisor continuously monitors video and computer feeds, watching for lost position updates, poor video or sidescan image quality, power issues, etc. Any unusual or interesting observations are recorded in the field notebook along with the video time stamp (local time).
8. At the end of the transect (or earlier if there are any equipment problems), the survey supervisor calls out "Stop recording" and the following actions take place:
    a. the helmsperson stops recording the vessel track and places the vessel in reverse just hard enough to stop the vessel in place with no drifting;
    b. the towfish operator brings the towfish to a point just below the surface if it isn't there already (we often end our transects right at the shore) and calls out "Towfish at surface";
    c. the survey supervisor turns off the recording functions of the computers and video console (noting the time in the field notebook) and turns off the DC power switches – calling out "Power off"
    d. the towfish operator brings the towfish on board, swings the davit arm in, raises the transceiver arm and calls out "Gear stowed"
9. The helmsperson then moves the vessel away from the shore to head to the next transect.

2.4 Data Processing

Every day of field survey requires at least two days of data processing back at the laboratory. We build a MapInfo[8] GIS project on an external hard drive (typically 1TB) from the survey data. The GIS project begins with a hydrographic chart background layer, we then add sidescan GeoTIFF images[9], towfish track positions and AVI video clips as in Vandermeulen (2007). An example GeoTIFF image is provided in Figure 7.

[8] Vandermeulen (2007) used ArcGIS. However, ArcGIS software has ongoing license fees and is very difficult to use.

[9] The sidescan data post processing software was updated from Vandermeulen (2007) in order to handle large files from long transects. We now use SonarWizMAP sidescan mosaic software – Chesapeake Technology Inc., Mountain View, California.

A corresponding screen shot from the video clip is provided in Figure 8. Note how the video 'ground truths' the sidescan imagery in real time.

By comparing the color and texture of the GeoTIFF images to the video clips, a color coded bottom classification can be generated from the transect data in the GIS project. We can typically discern bottom type (mud, sand, cobble, and boulder) and macrophyte cover (Figure 9).

3.0 RESULTS

As of 2010, the towfish system has been used to map approximately 170 km of Bras d'Or Lake shoreline, 70 km in the Isle Madame area (Cape Breton), five northern New Brunswick estuaries (Baie St. Simon, Tabusintac, Richibucto, Bouctouche, Cocagne), and the shorelines of Sambro and Halifax. This effort represents hundreds of kilometers worth of towfish transects.

In atidal (non-tidal) systems such as the Bras d'Or Lakes, the three person crew can run approximately 10 km worth of transect lines per day. If high tides must be captured (for sufficient vessel operating depth of at least ~60 cm), then 5 to 7 km of transect lines can be run in one day. The survey season typically runs from April through October, it is limited in the winter months by insufficient day-length and ice.

Figure 10 is a typical habitat map produced using the towfish data. It took 1.5 days to run this particular survey. Water clarity in this particular bay is not very good, and it is unlikely that remote sensing methods would have worked here.

DISCUSSION

The towfish system acts as a transect sampler, it provides an overview of habitat groups (e.g. urchin on cobble, or eelgrass on mud) over long, wide strips of the bottom in relatively short time frames. The value of the new towfish is its ability to use video to ground truth sidescan data in real time. The relatively narrow (1 or 2 m) field of view of the video camera is expanded to a full 30 m belt transect of bottom type information by the sidescan sonar. When post processing data in the laboratory, a boulder field seen in the video will correspond to a highly reflective and textured sidescan image. A skilled technician can compare video to sidescan to develop GIS project specific bottom classifications. These classifications have been confirmed by SCUBA and boat based (view box, grab sample) observations.

ACKNOWLEDGMENTS

Paul Keizer and Tom Sephton provided the original vision and support for the development of a nearshore mapping project at BIO. Peter Hurley and Ross Claytor allowed it to flourish in more recent years. Megan Wilson assisted on the surveys, patiently learning the quirks of the electronics. A special thank you to those 'volunteers' whom suffered many hours on deck handling the towfish cable. Megan Wilson, Brian Jones and Cam Lirette created the GIS projects.

Funding for equipment purchases came from Science Branch and the Oceans & Habitat Branch at BIO. Custom towfish design and equipment modifications were provided by Glen Morton (Ocean Sciences Division). Cable wiring was lead by Morley Wright and the team at Integrated Technical Services, Canadian Coast Guard. As always, the staff working in the BIO welding, machine and carpentry shops did a superb job of turning paper plans into reality.

REFERENCES

Vandermeulen, H. 2007. Drop and towed camera systems for ground-truthing high frequency sidescan in shallow waters. Can. Tech. Rep. Fish. Aquat. Sci. 2687: V + 17p.

Figure 1: 1kW Honda generator in protective 'doghouse'. Note elastic cord holding it down, and the black aluminum cowling (right side) to protect the power plugs and switches from rain and salt spray. A raised Plexiglas guide (not visible) on the black plastic floor aligns the rubber feet of the generator to hold it in a fixed position.

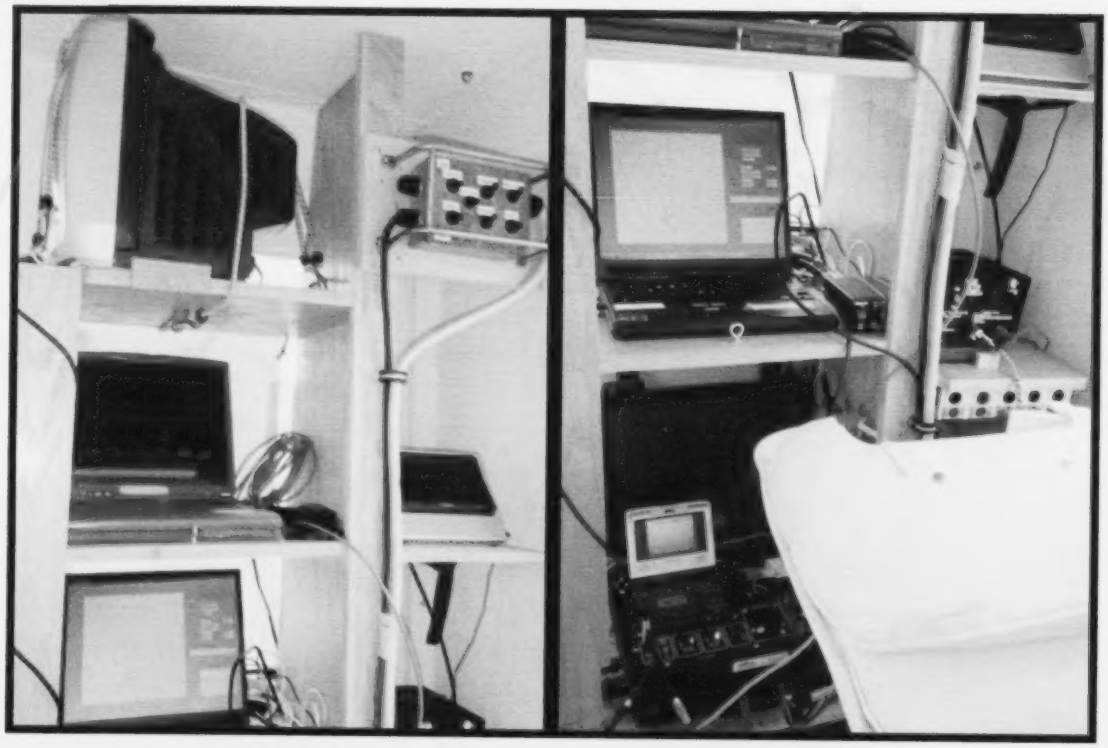

Figure 2: Custom hardwood shelf unit on back wheelhouse wall. Navigation computer and dGPS are located at the helm station (not shown). **Left** – Top half of shelf unit. Television monitor on top for towfish cable operator standing in wheelhouse door (all other electronics are operated by a second person in the wheelhouse proper). DC switchbox with protective metal cage is mounted to the right of the television. The shelves below the television hold the sidescan and transceiver computers. LCD monitor is on its own shelf to the right of the sidescan computer. **Right** – Transceiver computer on left with video overlay to its right. DC power supply on a separate shelf to the far right. SV-DV surface consol on bottom shelf with Sony miniDV video tape recorder (small blue screen). The white object in the foreground is a passenger seat (folded down).

Figure 3: New break away arm for the transceiver (submerged orange can) as deployed while on a survey transect. The break away arm described in Vandermeulen (2007) was slightly too long, and popped out of position too easily. This new version uses a spring loaded latch at the top of the arm to hold the arm in a vertical aspect while running survey transects. If an object hits the arm, the latch releases and the arm angles backwards via the pivot point where it bolts to the base of the davit. The arm is winched up and tied off to the davit when steaming between transects. The original hose clamps attaching the transceiver to the arm were replaced by a framed latch system for much faster attachment. The yellow cable in the water suspends the towfish.

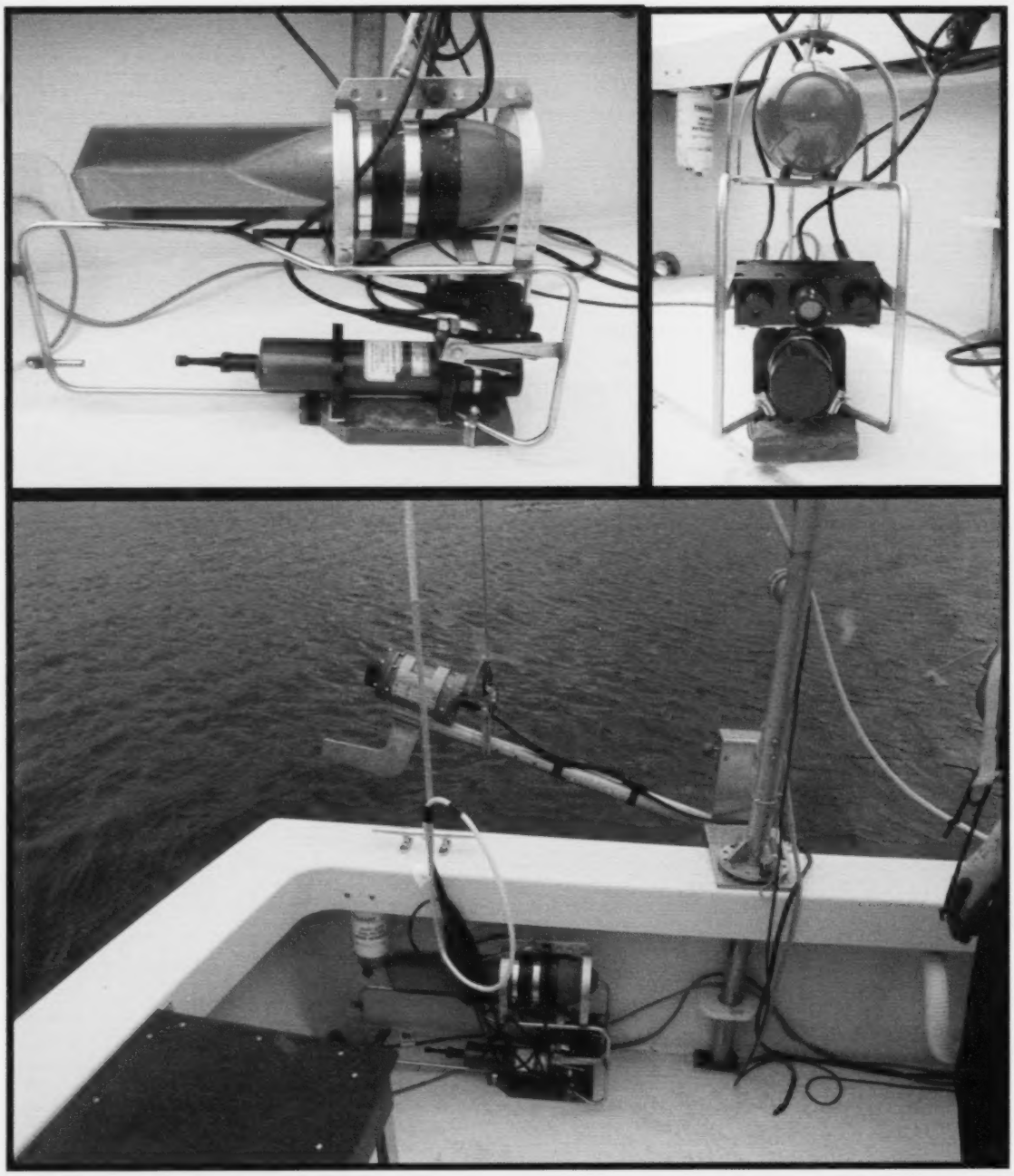

Figure 4: The new towfish. **Top Left** – Side view, starboard aspect - Welded stainless steel frame, clear plastic tailfin. A lead weight clamped to the very bottom of the frame provides stability while towing. The positioning transponder (green tube with black rubber cap) is attached to the frame just above the lead weight via two 'U' shaped black plastic clamps. The camera and laser scale are bolted into a black plastic block just above the transponder. The red sidescan body is held to the frame by two large hose clamps. **Top Right** – Front view - Black feeds from main yellow towfish cable to camera and lasers visible. **Bottom** – Transceiver arm raised and towfish secured for travel to next transect location. Dark yellow polypropylene Kellem Grip for the towfish cable is just visible attached to the balance point of the towfish by a shackle.

Figure 5: New clutch block. Note the white plastic plates attached to the inside of the black metal frame just above the white clutch wheel. These plates, and the deeper groove in the wheel itself, hold the yellow towfish cable in place and prevent it from rising up and binding.

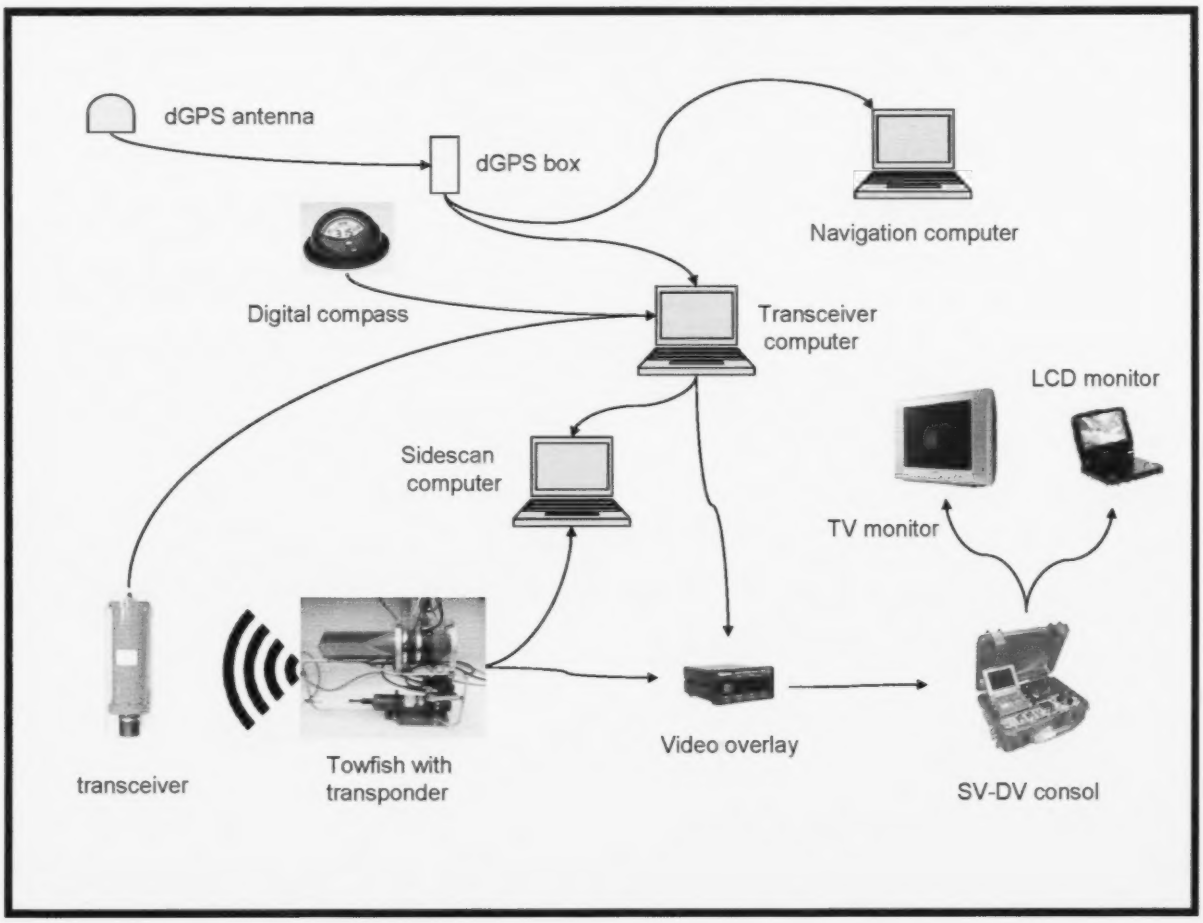

Figure 6: Schematic overview of the towfish and associated electronics.

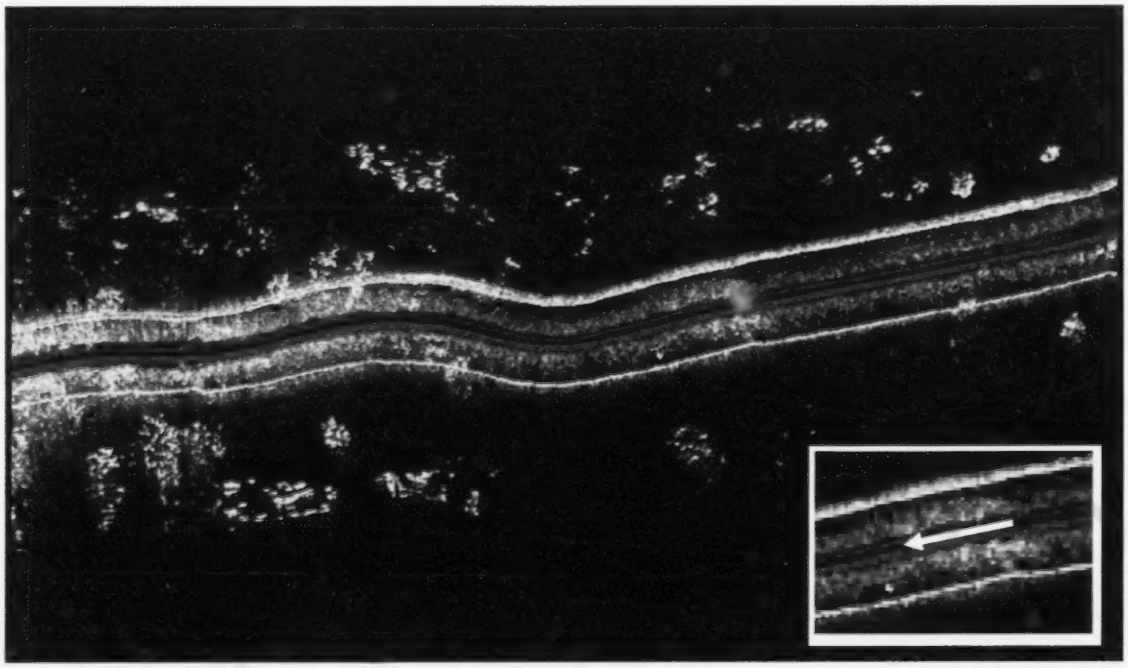

Figure 7: Sidescan image from towfish transect through a patchy eelgrass bed on a soft bottom. Individual clusters of leaves show up as bright golden specks aggregated into patches of various sizes against the dark brown background of acoustically non-reflective soft mud. Smaller patches are seen to the right, larger patches on the left. Total swath width (both transducers) is 30 m, 330 kHz transducer frequency, 8 dB gain setting. **Insert** – Detail of image at mid-line area. Arrow indicates placement and direction of towfish path. The acoustically bright (golden) bands and lines on either side of the darker towfish path are artifacts due to high energy returns close to the transducer surfaces. With the sidescan held in the towfish, mid-line acoustic shadows (Vandermeulen 2007) are no longer an issue as the towfish is 'flown' very close to sediment surface.

Figure 8: Screen shot of a video clip taken within the mid-line towfish path of the sidescan image in Figure 7. This confirms (ground truths) the sidescan image as the video shows patchy eelgrass on a soft bottom. The top lines of video overlay data come from the transceiver computer, indicating towfish position (45° 57.8258' north latitude by 61° 07.2418' west longitude) and local time stamp. The bottom lines are internally generated (I) by the overlay hardware, GMT time stamp and date.

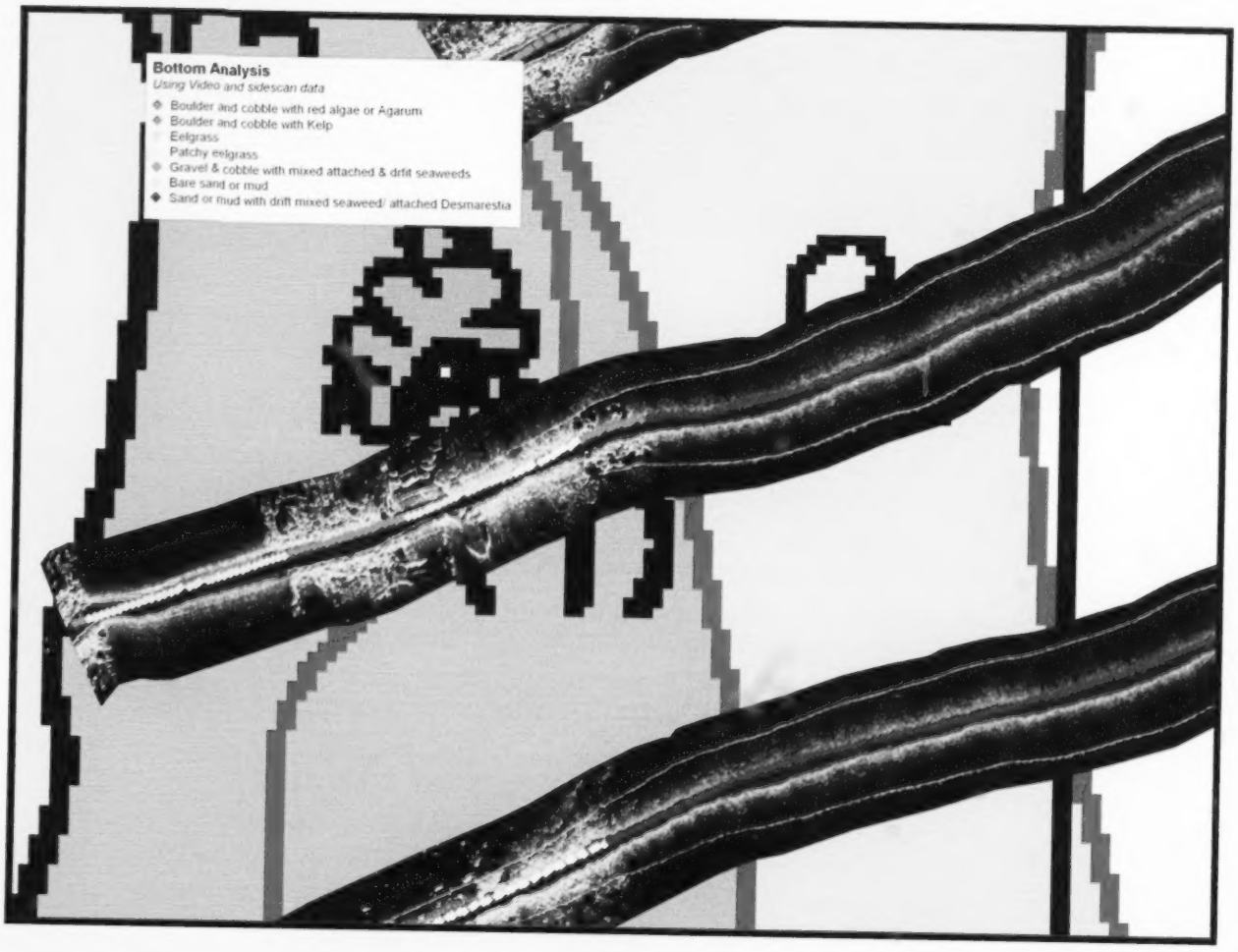
Bottom Analysis
Using Video and sidescan data
Boulder and cobble with red algae or Agarum
Boulder and cobble with Kelp
Eelgrass
Patchy eelgrass
Gravel & cobble with mixed attached & drift seaweeds
Bare sand or mud
Sand or mud with drift mixed seaweed/ attached Desmarestia

Figure 9: Screen shot of a typical bottom type classification in Map Info GIS made from the towfish data (video and sidescan). The color coded classification has been placed along the mid-line (towfish track) of the sidescan images. With a few exceptions due to habitat 'patchiness', the classification is accurate for the full 30m width of the sidescan imagery for each transect.

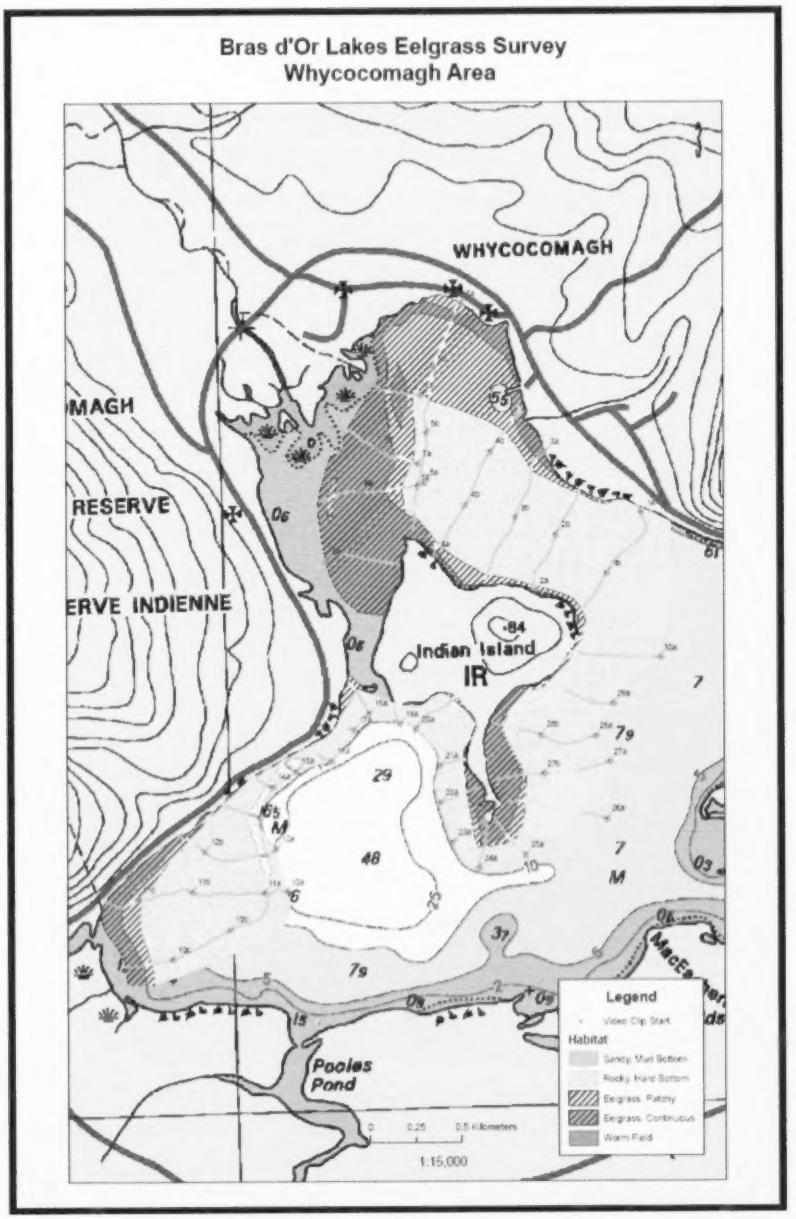

Figure 10: A map generated by a towfish bottom classification. Video clip positions are indicated along the towfish transects. Bottom type is interpolated between transects.